BIOPHYSICAL INTERDISCIPLINARY TROPHIC STUDIES (BITS)

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LONG-TERM GOALS

The long-term goal of our research is the development of data-based models to predict ecological relationships between plankton and the physical environment in the sea.

OBJECTIVES

Understanding the marine ecosystem is limited by man's inability to observe life in the sea on scales in time and space which most directly impact individual animals. In lieu of the ability to make direct observations of the animals and their environment, much of our knowledge about how they live is inferential. Our objectives include the development of instrumentation and methods of deployment to better sense small zooplankton and micronekton. As we develop new methods and sensors, we apply those advances during cruises in a variety of marine environments, including both oceanic and coastal sites; collecting and interpreting the data with the objective of understanding the interrelations of phytoplankton, zooplankton, the benthos, and their collective physical environments.

APPROACH

We develop and use multi-frequency acoustical instrumentation operating from several hundred kilohertz to several megahertz to detect zooplankton. The sensors measure the distribution of biomass, by size, between tens of microns and centimeters. These sensors are used on moorings, lowered from, or towed by ships, or as inverted echo sounders in shallow water. The data collected are used to: a) observe and understand the relationships between primary and secondary producers; and b) to observe distributions of the animals in relation to their food and physical environment. They also feed continuing engineering development efforts directed at improving the sensors, their user interfaces and the software used to transform the acoustical data to plankton size-abundance estimates. The

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use of this technology is rapidly growing in the scientific community. We continue to train biological oceanographers who wish to use multiple high frequencies of sound as a tool in their own research, providing access to the most advanced multi-frequency acoustical sensors and software with which they can convert acoustical measurements of volume scattering strengths to biomass - size spectra, thereby shortening their "learning curves".

WORK COMPLETED

We have completed the instrument development and data acquisition phases of our work under this contract and are analyzing and interpreting data, for publications of our own, and jointly with several other PIs with whom we have common data or common interests.

RESULTS

It is well established in science, that as technology is developed to observe at both larger and smaller temporal and spatial scales, one often discovers new phenomena. Within the last three or four years, we have developed quantitative, calibrated acoustical instruments, and methods for their deployment, which can resolve structures with vertical scales on the order of 10's of centimeters at distances of meters and temporal sampling intervals of minutes. These structures have physical, biological, chemical, optical and acoustical signatures. Initial deployments of our new high resolution TAPS technology, in 1996, with cooperating PIs from Oregon State University and the University of Rhode Island, revealed previously unresolved highly aggregated, dense, "thin layers" of zooplankton. These layers can consist of phytoplankton and zooplankton with in-layer densities that may range up to 1000 times the densities just above or just below the structure. These data lead to an observation that, when present, such concentrations of living material will have an impact on many aspects of marine ecology, e.g., growth dynamics of the phytoplankton and feeding success, reproductive behavior and predation by higher trophic levels. Retrospective analyses of our acoustical data from many geographic locations reveal that these zooplankton structures are widespread and are relatively common (e.g. Holliday, et al [in press]). These analyses also reveal that the densities of these structures were seriously underestimated due to the low resolution instruments available early in this decade, and by the smearing of data in the vertical due to deployment of the instruments from ships that move in response to the sea's surface.

Advances in acoustical and optical technology are also driving efforts to use advanced, high resolution sensors to guide efforts to directly sample both the plankton and the physical environment in very small (e.g., 10's of cm vertical scale) structures. With such tools, we can focus our plankton sampling and begin to study "who" is in the layers, and "why" they may be there. Equally importantly, we can relate their distributions to currents and current shear. In other words, we can now begin to investigate the processes that lead to the formation, maintenance, and dissipation of these structures. This is the first step on the road towards prediction.

We have been completing some analyses of data collected during a cooperative experiment with scientists from URI, OSU and UCSB in 1996 at East Sound, Orcas Is, WA. Some significant results of our work with small scale structures (in this case thin layers) include:

* Thin layers can be intense enough to dominate acoustical signatures throughout the water column.
* Thin layers have the potential to dominate biological dynamics in the water column.
* Temporal and spatial scales of thin layers can be hours to days and hundreds of meters to kilometers, respectively.
* Observed variations in the composition of different thin layers suggest differences in the mechanisms of formation, maintenance and erosion, as well as differences in temporal evolution.
* Interactions between stratification, currents and current shear can be important in layer formation, maintenance and dissipation.
* Zooplankton often aggregate into thin layers, with different species and size classes having different degrees of association with phytoplankton layers.
* Zooplankton may avoid some optically detected thin layers.

Tracor's scientists have continued the process of improving the quality of the acoustical data streams from the sensors, making the sensor systems more reliable and easier to use, and improving the signal and data processing, especially focusing on the (inverse calculation) software which transforms the acoustical data into estimates of zooplankton abundance by size. We have also processed and displayed a large multi-frequency data set and the derived biomass spectra from the Arabian Sea. Several papers based on those data are being prepared.

IMPACT

The acoustical signatures of small scale, but intense zooplankton layers can directly impact the performance of current and planned Navy sensors in areas such as mine warfare, spec warfare and torpedo performance. Understanding a marine ecosystem requires measurement of pattern (spatial distribution) and sensing of the processes happening within that pattern. With the advent of the TAPS technology, pattern in assemblages of zooplankton has become accessible to non-acoustician biologists in a quasi-synoptic form. Temporal estimates from our moored acoustics and repetitive occupation of fixed stations and transects are providing insight into the time scales and dynamics of the processes that result in and modify pattern.

Findings related to potential and current impacts on Navy systems are:

* Acoustical scattering from thin layers can be of the same magnitude as is created by the wake of a surface ship (often near the same depths).
* Acoustical scattering by layers could substantially impact the performance of

high frequency, diver-operated, hand-held sonars.

* Diel migrations of small zooplankters from on, in, or near the bottom can change volume reverberation levels in the water column by over 30 dB.
* Emergence of benthic animals into the water column can modify the structure and topology of the seabed. This can impact the volume and surface scattering of high frequency sound as it interacts with the bottom.

TRANSITIONS

As discussed under related projects, below, we are continuing to make the TAPS technology widely available to other investigators via short term leases, purchases and collaboration on specific projects. An important part of this effort is training in the use of inverse methods and the software used to convert the TAPS acoustical data to biovolume - size spectra. A description and an example of our multi-frequency technology is included in a new text (Medwin and Clay, 1997). This should further accelerate interest in this technology within the bioacoustics and biological oceanography communities.

RELATED PROJECTS

Data collection on Georges Bank continues, with a TAPS built for Drs. Mark Berman and Jack Green (NOAA / NMFS Narragansett, RI). Under separate (ONR DURIP) funding, we are building a TAPS for Drs. Sharon Smith and Harry DeFerrari (RSMAS, Univ. of Miami) in their research programs. We are also upgrading a TAPS for Dr. Peter Ortner (AOML / NOAA). TAPS has also been used in ONR sponsored research on scattering from benthic assemblages in the San Juan Islands of WA. Observations of diel migrations from the benthos into the water column from this work are the subject of detailed investigation by one of Dr. Peter Jumars' graduate students at the University of Washington. A TAPS was used on a SeaSoar and on CTD casts in the ONR Arabian Sea project during several JGOFS cruises. The NSF-sponsored Land Margin Ecosystem Research program in the Chesapeake Bay and a NOAA Sea Grant study on the ingress of shrimp larvae from the sea into the Ogeechee estuary in Georgia are also TAPS users. ORSTOM (France) is also currently using one of our TAPS in a program of research on the food web which supports the tuna population in the equatorial Atlantic (PICOLO). Funding for these investigations is independent of our ONR work, but the technology used was a direct result of our ONR support. Investigators at these institutions using TAPS acoustical data and its derivative products (zooplankton abundance and distribution by size) to describe and analyze the plankton ecosystem in their own special areas of interest.

REFERENCES

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